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INVESTIGATION OF THE EFFECTS OF GASOLINE – ETHANOL FUEL BLEND ON THROTTLE RESPONSE AND INTAKE AIR TEMPERATURE IN A NATURALLY ASPIRATED S.I. ENGINE

SANJAY CHHALOTRE[1], PRASHANT V. BAREDAR[2] & SANJAY SONI[3]

[1,2]*Energy Center, Maulana Azad National Institute of Technology, Bhopal, Madhya Pradesh, India*

[3]*Department of Mechanical Engineering, Maulana Azad National Institute of Technology, Bhopal, Madhya Pradesh, India*

ABSTRACT

Ethanol-gasoline fuel blend is the most encouraging substitute to the gasoline fuel for all new generation spark ignition (S.I.) engines. By the adding ethanol which is oxygenated in nature, a higher level of oxygen and octane rating is achieved, which in turn increases the volumetric efficiency and combustion efficiency of the naturally aspirated S.I. engine, with a reduction in heat loss after the combustion, as compared to the pure gasoline driven engine. In this research paper, we investigated the effect on throttle response of naturally aspirated S.I. engine and the variation of intake air temperature due to the engine heat loss by using ethanol blend (E0, E10, E20, and E30) in real driving conditions with the aid of a Launch C Reader VI code engine scanner. The result shows that the blending ratio has a direct impact on the fuel efficiency of the vehicle which was enhanced from 18.6 to 24 km/L respectively for E0 to E30. The throttle response at low speed is also improved in terms of achieving higher engine speed (~2000 rpm). A throttle valve opening of 11.2% is required in the gasoline driven engine while only 9.6 % is required in E30.

KEYWORDS: Ethanol-Gasoline Blend; Heat Loss; Intake Air Temperature; Spark Ignition Engine & Throttle Response

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Original Article

INTRODUCTION

A swift depletion of conventional petrol-fuels coupled with their rocketing costs and exhaust gas emissions require a rigorous search for alternative fuels. Although the fuel economy and the level of pollutants in exhaust gases of internal combustion engines are greatly improved from the past on account of numerous technologies and will probably continue to improve. The most promising substitutes for petroleum fuels is ethanol or ethyl alcohol (C_2H_5OH). It may be employed as a fuel or an additive in internal combustion engines without any need for large and extra modifications in the air intake system and fuel injection system of the engine [1, 2].

A cardinal advantage with ethanol is that it can be made from a number of non-petroleum sources. Ethanol can be produced by biochemical pathways such as hydrolysis and fermentation of carbohydrates which occurs naturally and abundantly in plants such as sugarcane and from starchy materials such as corn and potatoes [3, 4]. Hence these fuels can be produced from cheaply and amply available raw materials.

The physical and thermal properties of ethanol show similarities with gasoline [5]. Ethanol is preferred over gasoline mainly due to a substantially lower harmful exhaust emission and the low green house effect. In

addition, ethanol can be easily and homogeneously blended with gasoline arising its octane number and therefore, popularity.

There are certain limitations of alcohols used as a fuel such as low energy content (for e.g., (in order to produce the same amount of energy, only half the quantity of gasoline fuel is required as compared to the alcohol), poor ignition and low flame temperature characteristics [6]. Ethanol also has a propensity to absorb moisture from the air, consequently, it is more corrosive than gasoline. However, in practice, ethanol may do well as a fuel in S.I. engines, either as pure ethanol, or when used as a blend. By the addition of ethanol, octane number is improved. In addition, the fraction of pollutants and knocking agents are reduced. [7, 8]. Straight alcohols reduce the life of rubber and plastic components of fuel injection system thus they are not recommended to be used as a fuel in S.I. engines. It is the alcohol-gasoline blends which are used on some scale. The aim of blending is to reduce the load on existing fossil-based fuels. Simultaneously, they are researched to evaluate their feasibility to replace the conventional fuels and to fulfill the different combustion requirements.

Gasohol, a word derived from gasoline and alcohol where gasoline is 90% and ethanol is 10%. Two usually employed blends are E85 (85% ethanol) and E10 (10% ethanol, also known as gasohol). E85 is basically an alcohol fuel with only 15% gasoline. E85 eradicates some major issues found in the addition of the pure alcohol such as cold starting and tank flammability. E10 reduces to a great extent, the use of gasoline with no modification required in the engine [7].

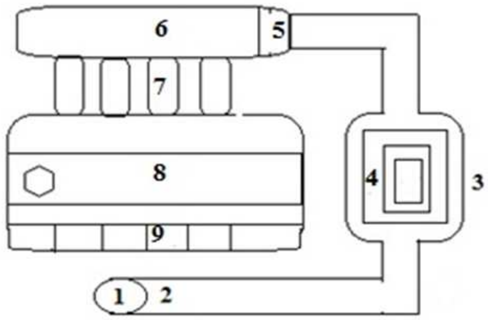
A major benefit for improving the I.C. engine technology with the help of blend fuel is to minimize the exhaust gas pollutants. The key exhaust gas pollutants from the burning of gasoline fuels are oxides of nitrogen (NO_x), unburned hydrocarbons (UBHC) and carbon monoxide (CO) [11]. The impact of ethanol fuel blends (E10, E20, E40, and E60) was noted at varying compression ratios ranging from 8:1 to 13:1, on exhaust gases. With the higher ratio of ethanol of more than 20%, the reduction in unburnt hydrocarbons, carbon monoxide and oxides of nitrogen were reported [12]. Ethanol fuel blends (E25, E50, E75, and E100) were investigated with a compression ratio of 6:1 at a constant load and speed in a small petrol engine. The experimental results showed that the engine power was increased by about 29% when E50 was fed as compared to pure gasoline fuel. Moreover, the BSFC, and CO, CO_2, HC and NO_x emissions were decreased by a significant amount [13].

As compared to the gasoline fuel, the process of combustion of the oxygenated ethanol-gasoline blend and the rate of evaporation of the blended fuel in the internal-combustion engine is faster. For this reason, engines using ethanol have higher efficiency due to quicker combustion with low heat loss [14]. The level of UBHC and other exhaust gas pollutants such as CO, CO_2, and NO_X would depend upon the type of fuel used and the ratio of air-fuel mixture fed for combustion at different engine load and speed conditions. In general, because of lower heat content (~6400 Kcal/kg) of ethanol as compared to value of gasoline (~10500 Kcal/kg), specific fuel consumption increases and harmful NO_X emissions decreases [15]. However, tests in S.I. engines reflect an inverse relationship between ethanol ratio and engine output power (and torque values) [16, 17].

Variable fuel blends were investigated by numerous researchers to evaluate performance and exhaust emissions employing different working conditions [16, 17]. Published work reflects that when ethanol content is raised to 20%, a vital-drop in HC and CO is observed. However, when ethanol is added beyond 40%, a destabilization in engine speed was noted on account of poor air-fuel ratio [16, 17]. They concluded that the optimal ethanol-gasoline blend is around 20-30% vis-à-vis emissions in gasoline engine [18]. Experiments were performed on a four-cylinder SI engine (Toyota, Tercel-3A)

with 3/4th throttle valve opening and variable engine speed (1000 to 4000 rpm). It was demonstrated that the ethanol addition enhanced the brake power, volumetric efficiency, thermal efficiency, and fuel consumption by considerable amount [19]. Ethanol addition also reduced the brake specific fuel consumption by 2.4% and equivalence air-fuel ratio by 3.7%. The experimental outcome clearly shows that ethanol-gasoline blended fuels with 20% ethanol provide the best result in terms of engine performance and exhaust emission [19]. Previous investigations show that many experimental studies have been conducted on the engine performance and emissions while using different ratios from E0 toE100 in spark ignition engines [20, 21].

As far as authors’ knowledge is concerned, there is no study so far on the engine performance and fuel economy affected by the variation in intake air temperature of naturally aspirated MPSEFI engine fueled by ethanol-gasoline blend. In continuous operation of the vehicle, on account of heat loss by the engine, the entire engine compartment along with air intake system and intake manifold gets heated above the atmospheric temperature and consequently, heat the intake air coming from the atmosphere at atmospheric temperature. This pre-heated air above the atmospheric temperature when enters for combustion, lowers the density of air, resulting in the reduction of the number of moles of oxygen, which in turn causes a drop in the volumetric and combustion efficiency. It also increases the extent of incomplete combustion, loss of power and formation of pollutants even at a lower engine speed [22]. A schematic of air intake system is represented in Figure 1.



1. Bellmouth, the Fresh Air at Atmospheric Temperature Enter for Combustion
2. Hose Intake Air
3. Air Filter Assembly
4. Air Filter
5. Throttle Body
6. Plenum
7. Runner
8. Engine
9. Exhaust Manifold

Figure 1: The Schematic Block Diagram of Air Intake System

The purpose of this experimental work is to analyze the effect of variation in intake air temperature and throttle response of naturally aspirated spark ignition engine fueled by E0, E10, E20, and E30 in actual driving conditions and variable traffic scenarios using a Launch C Reader VI code engine scanner. They have been tested in various engine speeds ranging from idle speed 700 to 2000 rpm. This will aid in determining the effect on throttle response and fuel consumption during normal driving practices. In this research work, India's moderate climatic condition has been taken as the reference.

METHODOLOGY

The experiments were conducted on a Chevrolet Spark (VEHICLE IDENTIFICATION NO. MA6MFBC1CCT003533, ENGINE NO. B10S1809119KC2, Variant - CHEVROLET SPARK BASE BS4, REGISTRATION NO. MP04CK3375) four-cylinder 900 cc Sequential Electronic Multipoint Fuel Injection System (SEMFIS) equipped spark ignition engine. The general specification of the test engine is given in Table 1.

Table 1: Specifications of the Engine

Variables	Details
Engine Type	SI 8V SOHC 4CYL Inline Naturally Aspirated MPSEFI
Total displacement	995 m^3
Compression ratio	9.3
Maximum power at 5400 RPM	46.3 kW
Maximum torque at 4200 RPM	90.3 N-m
Stroke length	67.5 mm
Bore	68.5 mm
Valve stem diameter	Inlet: 5.465 mm Exhaust: 5.440 mm
Valve diameter	Inlet: 35.5 mm Exhaust: 31.7 mm
Firing order	1-3 - 4-2
Fuel	Gasoline

For the experiment, the data collection was carried out on actual driving conditions with variable engine speed between 700 rpm to 2000 rpm with different fuel blend ratios. During each trial run with a different fuel blend, the variation in opening percentage of throttle valve and intake air temperature (because of engine heat dissipation rate) was recorded with the help of two J-type thermocouples (model-INDEX 48+) (range 0 ^{o}C to 960 ^{o}C), after a fix time interval of 20 minutes. A Launch C Reader VI code engine scanner was used to record changes which occurred in technical parameters such as opening percentage of throttle positioning valve, ignition timing, air intake temperature, intake manifold pressure and fuel efficiency of vehicle (kilometer per liter) was recorded with respect to different ethanol-gasoline fuel blend E0, E10, E20, E30 and at different engine speeds ranging from 700 to 2000 rpm. Each experimental reading was taken after the engine operating temperature reached a steady state condition of 93°C. Various pictures of the test vehicle are shown in Figure 2(a) and 2(b).

Figure 2(a): Temperature Sensors Installed in the Test Engine

Figure 2(b): A View from Inside the Vehicle while Driving

The ethanol gasoline fuel blend was prepared on a volume basis. The ethanol was bought from Divya Science Centre, Bhopal, India (D.L. No.: 49/20B/2003, 50/21B/2003). The purity ratio of ethanol was 99.9%. The fuel properties of pure ethanol obtained from the manufacturer and the literature [23] and they were found to be similar. The properties of the test fuels are shown in Table 2 [23] and Table 3 [24].

Table 2: Chemical and Physical Properties of Gasoline and Ethanol Fuels.

	Gasoline	Ethanol
Chemical Formula	$C_{5–10}H_{12–22}$	C_2H_5OH
CAS Number	86290-81-5	64-17-5
Molecular Weight mass%	106.22	46.70
Carbon mass%	87.50	52.20
Hydrogen mass%	12.50	34.70
Oxygenmass%	00.00	34.70
Density, (g/ml)	0.74	0.78
Boiling temperature, °C	27-225	78.25
Reid vapor pressure, KPa	53-60	17
Research octane no.	90-100	108.6-110
Motor octane no.	82-92	92
LHOV kJ/kg	349	923
LHV MJ kg^{-1}	44.0	26.9
Freezing point, °C	−40	−114
Viscosity mm^2/s	0.5-0.6	1.2-1.5
Flash point, °C	−45 to −13	12-20
Auto ignition temperature, °C	257	425

Table 3: Properties of Different Ethanol - Gasoline Blended Fuels.

Variable	Ethanol %			
	E0	E10	E20	E30
Heat of combustion (MJ/kg)	44.133	42.447	40.672	38.673
Reid vapour pressure (KPa)	35.00	59.53	54.61	53.31
Research octane number	84.8	88.3	93.4	98.9
Density at 15.5 C (kg/l)	0.7678	0.7760	0.7782	0.7794
Distillation temperature (C) IBT	38.5	39.5	40.3	40.7
10 vol.%	57.2	52.3	55.4	55.7
50 vol.%	93.5	71.8	71.6	72.5
90 vol.%	156.0	143.7	143.1	142.7
End point	181.7	176.1	176.6	176.5

RESULTS AND DISCUSSIONS

Impact of Blending on Throttle Response

This experimental investigation has been carried out to understand the effect on engine throttle response by using different gasoline fuel blends and variation of intake air temperature. The chemical and physical properties of the ethanol fuel blend directly influenced the engine performance in terms of the combustion process and efficiency of the engine. The laminar burning rate of ethanol fuel blend increased the flame velocity and led to the reduction in combustion duration as shown in Figure 3.

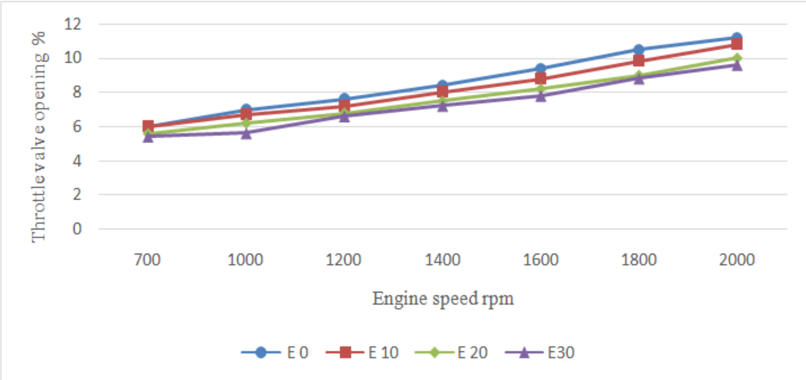


Figure 3: Change in Engine Speed in Relation to Opening Percentage of Throttle Valve

It can also be observed that as the ethanol blend percentage was increased from E0, E10, E20, and E30, the same engine speed was obtained as with the gasoline fuel, by the minimum opening of a throttle valve. In actual conditions, the low opening of throttle valve restricted the mass flow rate of air which was required for combustion but on account of ethanol addition, more oxygen was available (as ethanol is oxygenated) for the complete combustion even at lower engine speeds.

Effect of Blending on Mileage

The ethanol gasoline blend has a lower heating power as compared to gasoline. The experimental investigation showed a lower fuel consumption per kilometer as the percentages of the blend was increased as shown in Figure 4. When pure gasoline was fed (E0), the vehicle traveled 18.67 in 1 L. As the ethanol % was enhanced to 10, 20 and 30, the distance traveled was increased to 21.35 km, 22.8 km, and 24 km, consuming 1 L of the fuel blend.

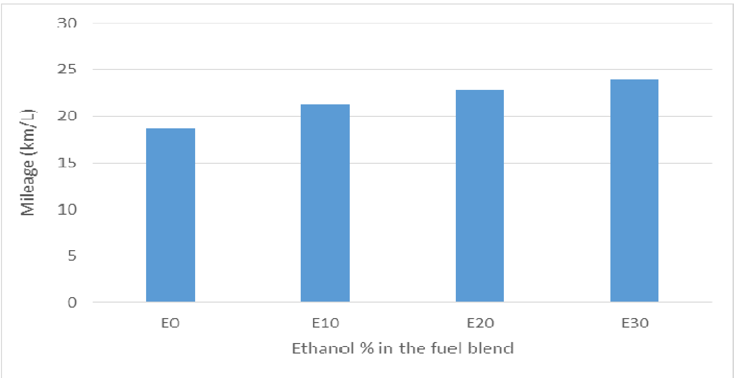


Figure 4: Graph Representing Mileage Versus Ethanol Blending Percentage

Ethanol is an oxygenated fuel and therefore undergoes complete combustion in the cylinder, which in turn enhances the combustion and volumetric efficiencies. Consequently, fuel consumption, in real driving conditions, decreases with an increase in ethanol percentage in the fuel blend. The tests were conducted in both lean and dense traffic.

Variation in Intake Air Temperature

The air from the atmosphere enters into the engine for combustion through the air intake manifold system. The properly designed air intake system allows the atmospheric air to enter for combustion with higher velocity and turbulence, which enhances the evaporation rate of fuel. The intake manifold is located very close to engine unit and therefore is heated up to more than 60°C when the engine is fueled by gasoline as shown in Figure 5. However, increasing the temperature reduces the volumetric efficiency of the engine due to few reasons. Firstly, higher temperature reduces the air density and temperature at the start of the compression stroke, therefore, the higher the temperature throughout the rest of cycle, the greater is the potential problem of engine knock.

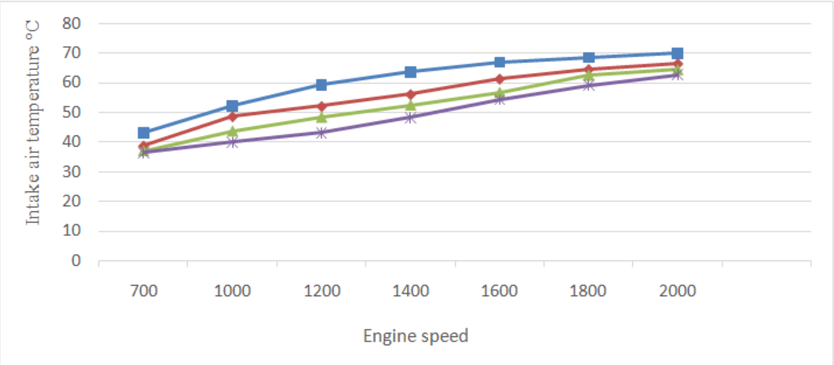


Figure 5: Variation in Intake air Temperature with Respect to Engine Speed

With ethanol blend, it is observed that the heat dissipation rate after combustion is lesser as compared to gasoline-fueled engine, as the blend percentages were increased. Ethanol exhibited a high latent heat of vaporization and lower adiabatic flame temperature with respect to gasoline which in turn dropped the temperature of the charge during the end of compression stroke which led to the low values of exhaust gases and engine compartment temperature.

CONCLUSIONS

This experimental study was performed to investigate the effect of ethanol blending with gasoline in different ratios (E0, E10, E20, E30) on the throttle response and engine's heat dissipation rate. This investigation was carried out in variable traffic scenarios in real driving conditions. It is found that the impact was positive and can be further researched for more blending ratios on variable parameters. Specific conclusions are as under:

- The throttle response at low engine speed was improved as the ethanol fuel blend ratio was increased from 0% to 30% by volume.
- The fuel efficiency (km/L) was improved from 18.67 km/L to 24 km/L when the ethanol content was enhanced from 0% to 30%.
- Improved combustion and volumetric efficiency with minimum heat loss were found in the engine compartment as compared to gasoline fuel.

REFERENCES

1. *V.S. Sikarwar, M. Zhao, P.S. Fennel, N. Shah, E.J. Anthony, Progress in biofuel production from gasification, Prog. Energ. Combust. 61 (2017) 189-248.*
2. *.M. Bergthorson, M.J. Thomson, A review of the combustion and emissions properties of advanced transportation biofuels and their impact on existing and future engines, Renew. Sust. Energ. Rev. 42 (2015) 1393-1417.*
3. *S. Prasad, A. Singh, H.C. Joshi, Ethanol as an alternative fuel from agricultural, industrial and urban residues, Resour. Conserv. Recy. 50 (2007) 1-39.*
4. *V. Acharya, B.R. Young, A review of the potential of bio-ethanol in New Zealand, Bull. Sci. Technol. Soc. 28 (2008) 143-148.*
5. *. Gravalos, D. Moshou, T. Gialamas, P. Xyradakis, D. Kateris, Z. Tsiropoulos, Emissions characteristics of spark ignition engine operating on lower-higher molecular mass alcohol blended gasoline fuels, Renew. Energ. 50 (2013) 27-32.*
6. *M.A. Ghadikolaei, Effect of alcohol blend and fumigation on regulated and unregulated emissions of IC engines-a review, Renew. Sust. Energ. Rev. 57 (2016) 1440-1495.*
7. *A. Szklo, R. Schaeffer, F. Delgado, Can one say ethanol is a real threat to gasoline? Energ. Policy 35 (2007) 5411-5421.*
8. *B.M. Masum, H.H. Masjuki, M.A. Kalam, I.M. Rizwanul Fattah, S.M. Palash, M.J. Abedin, Effect of ethanol–gasoline blend on NOx emission in SI engine, Renew. Sust. Energ. Rev. 24 (2013) 209-222.*
9. *L.M. Rodriguez-Anton, F. Gutierrez-Martin, Y. Doce, Physical properties of gasoline, isobutanol and ETBE binary blends in comparison with gasoline ethanol blends, Fuel. 166 (2016) 73-78.*
10. *C.K. Westbrook, Biofuels Combustion, Annu. Rev. Phys. Chem. 64 (2013) 201-219.*
11. *J.M. Beer, Combustion technology developments in power generation in response to environmental challenges, Prog. Energ. Combus. 26 (2000) 301-327.*
12. *H.S. Yücesu, T. Topgül, C. Çinar, M. Okur, Effect of ethanol–gasoline blends on engine performance and exhaust emissions in different compression ratios, Appl. Therm. Eng. 26 (2006) 2272-2278.*
13. *M.B. Celik, Experimental determination of suitable ethanol-gasoline blend rate at high compression ratio for gasoline engine, Appl. Therm. Eng. 28 (2008) 396-404.*
14. *S. Kumar, S. Neetu, P. Ram, Anhydrous ethanol: a renewable source of energy, Renew. Sust. Energ. Rev. 14 (2010) 1830-1844.*
15. *Khalaf, Hatam Y., and Hadi G. Rashid. "Fully and Naturally Cancellation Fuzzy Module."*
16. *H. Bang-Quan, W. Jian-Xin, H. Ji-Ming, Y. XiaoGuang, X. Jian-Hua, A study on emission characteristics of an EFI engine with ethanol blended gasoline fuels, Atmos. Environ. 37 (2003) 949-957.*
17. *M.K. Balki, C. Sayin, M. Çanakci, The effect of different alcohol fuels on the performance, emission and combustion characteristics of a gasoline engine, Fuel. 115 (2014) 901-906.*
18. *P. Iodice, A. Senatore, G. Langella, A. Amoresano, Effect of ethanol-gasoline blends on CO and HC emissions in last generation SI engines within the cold-start transient: an experimental investigation, Appl. Energ. 179 (2016) 182-190.*
19. *I. Schifter, L. Diaz, R. Rodriguez, J.P. Gomez, U. Gonzales, Combustion and emissions behavior for ethanol-gasoline blends in a single cylinder engine, Fuel. 90 (2011) 3586-3592.*

20. *M. Al-Hasan. Effect of ethanol-unleaded gasoline blends on engine performance and exhaust emissions, Energ. Convers. Manage. 44 (2003) 1547-61.*

21. *S. Phuangwongtrakul, W. Wechsatol, T. Sethaput, K. Suktang, S. Wongwises, Experimental study on sparking ignition engine performance for optimal mixing ratio of ethanol-gasoline blended fuels, Appl. Therm. Eng. 100 (2016) 869-879.*

22. *S.K. Thangavelu, A.S. Ahmed, F.N. Ani, Review on bioethanol as alternative fuel for spark ignition engines, Renew. Sust. Energ. Rev. 56 (2016) 820-835.*

23. *Sehajpal, P. K., and P. J. Singh. "Effect of temperature, leaf wetness period, light and darkness on development of Botrytis blight (Botrytis gladiolorum Timm.) of gladiolus (Gladiolus grandiflorum L.)." Int J Res Appl Nat Soc Sci 2 (2014): 211-218.*

24. *J.B. Heywood, Internal combustion engine fundamentals, New York: Mcgraw-Hill, 1988.*

25. *O.I. Awad, R. Mamat, O. M. Ali, N.A.C. Sidik, T. Yusaf, K. Kadirgama, M. Kettnere, Alcohol and ether as alternative fuels in spark ignition engine: A review, Renew. Sust. Energ. Rev. 82 (2018) 2586-2605.*

26. *I. Gravalos, S. Loutridis, D. Moshou, T. Gialamas, D. Kateris, Z. Tsiropoulos, P. Xyradakis, Detection of fuel type on a spark ignition engine from engine vibration behavior, Appl. Therm. Eng. 54 (2013) 171-175.*